LAVA FLOWS AS SLOPE INDICATORS IN THE THARSIS REGION OF MARS

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Introduction: Considerable attention has recently been directed towards gaining an understanding of the geophysical (1,2), geochemical (3) and volcanological (4) evolution of the Tharsis region of Mars. Debate has centered upon the relative importance of tectonic uplift versus constructional volcanism as the primary mechanism for the production of the observed relief (5,6), together with the attendant implications that such interpretations would hold for lithospheric structure and crustal/mantle petrology. In part, any future choice between these two geophysical models will depend upon the identification of intra-regional surface deformations (as indicators of both temporal and spatial variations in crustal strength in response to progressive loading by the volcanic materials) and the detailed analysis of the distribution of the associated volcanic activity. Due to their propensity to flow downhill and their large age distribution (7,8), lava flows within Tharsis provide high fidelity information on these regional characteristics for the time of their emplacement (7). As part of a continuing effort to characterize the eruptive styles of martian volcanoes (9,10), some preliminary results from an analysis of the flow directions of 473 lava flows (all in excess of 20 km in length) are reported here to help describe the intra-regional volcano/tectonic features within Tharsis.

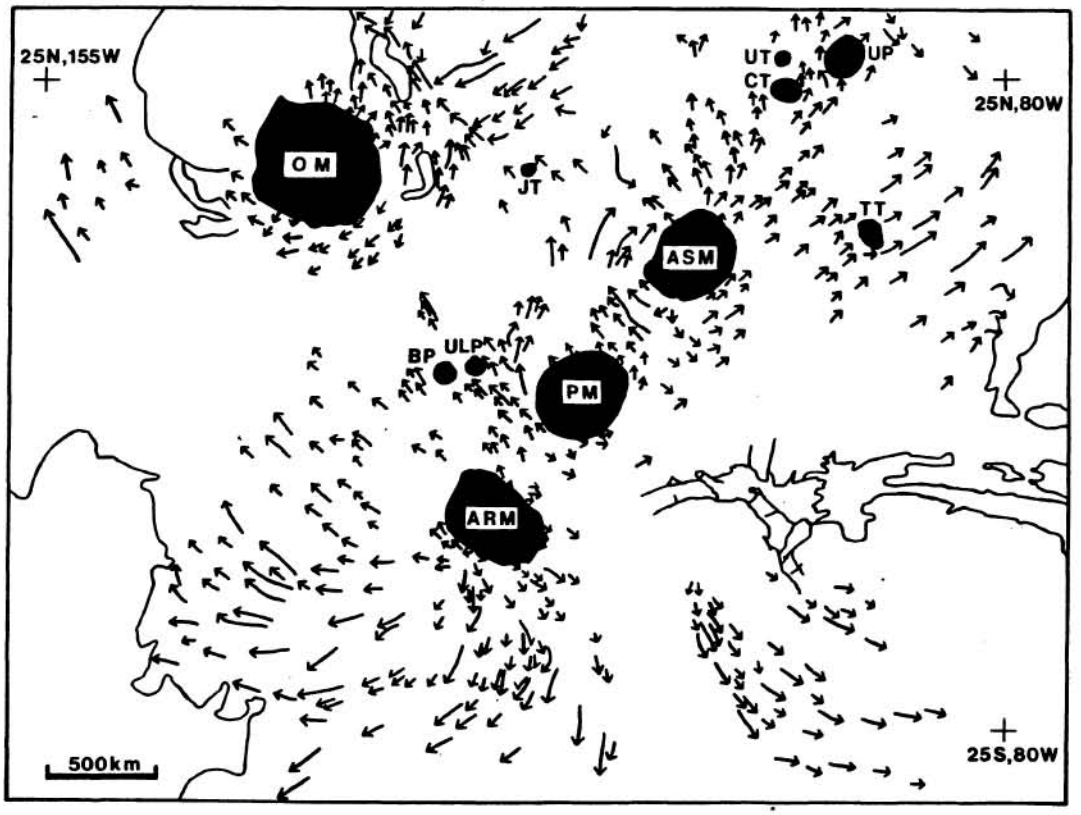

Figure 1: Distribution of all lava flows included within this analysis. Length of arrow is equivalent to length of lava flow and shows direction of flow. Volcanoes are shown in black with the following abbreviations: OM, Olympus Mons; ASM, Ascraeus Mons; ARM, Arsia Mons; BP, Biblis Patera; ULP, Ulysses Patera; JT, Jovis Tholus; CT, Ceraunius Tholus; UT, Ulanius Tholus; UP, Uranius Patera; TT, Tharsis Tholus. Also shown are the highland boundary in Memnonia, Valles Marineris, the Olympus Mons aureole and Echus Chasma.

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Volcanology: Regional mapping of the Tharsis lavas (Fig.1) permits vent areas which lack obvious volcanic constructs to be recognized; Syria Planum and an area west of Ceraunius Fossae are two such examples. Several small cones of probable volcanic origin have been identified in these localities (11), but their significance as source regions for large volumes of magma had not been previously reported. Subtle differences in eruptive style are also indicated within Tharsis. Lavas were not only erupted from the shield volcanoes; saddle regions between the three Tharsis Ridge volcanoes added considerable volumes of lava to the surrounding areas. These lavas were responsible for burying the lower flanks of Ascraeus and Pavonis Montes, postdating the shield activity. However, saddle eruptions were contemporaneous with activity from Arsia Mons (in apparent contradiction to the volcano ages inferred from crater counts; 4).

Flow directions north of Arsia Mons and east of Olympus Mons confirm earlier observations (7,12) that the regional slope of Tharsis is down toward the northwest, with a high existing between Arsia and Pavonis Montes and a low near Olympus Mons. The linear extent of this northwest slope is at least 2500 km, and there are also downhill gradients which extend away from Pavonis Mons toward the northeast for 2000 km, southeast from Syria Planum for 1200 km and westward from Arsia Mons for 1000 km (Fig.1). The absence of minor deviations from a straight-line path for most of these flows indicates that there are no additional topographic rises within central Tharsis which constitute as yet unrecognized vent areas. Rather than being constructed by lava from a large number of widely dispersed vents, it appears that the currently exposed lavas were erupted from only a few frequently reactivated centers.

Intra-Regional Deformation: Prominent amongst the local topographic features which are evident from the lava flow orientations (Fig.1) is a circumferential depression, or peripheral trough, which surrounds Olympus Mons. Also evident from Earth-based radar measurements (13), this depression extends to distances of 300-350 km beyond the basal escarpment of the volcano and has redirected northwest-flowing lavas from the Tharsis Ridge volcanoes toward Arcadia and Amazonis Planitiae. From the preserved record, no lava flows originating from Olympus Mons contributed to the lava pile which now constitutes central Tharsis, implying that this peripheral trough has been in existence for an extended period of time rather than being a relatively recent response to crustal loading.

In comparison to Olympus Mons, the other three large shield volcanoes are noteworthy for their apparent lack of influence on the surrounding plains. A subtle divergence of lava flows about 330 km west of Ascraeus Mons may mark the perimeter of a trough, but subsequent flows make this interpetation uncertain. Furthermore, no evidence for similar depressions around either Arsia or Pavonis Montes can be found, hinting at the uniqueness of the Olympus Mons trough. It is also remarkable that despite the apparent large differences in ages for the lavas (7,8), there was almost no tilting of the surface units during the entire period represented by the exposed surface materials. Evidently lavas erupted at significantly different times (as suggested by their crater densities) all travelled in response to the same slopes, rather than different directions due to progressive deformation during the extended period of volcanism. It therefore appears that the crustal structure beneath Tharsis was sufficiently rigid to support the changing load associated with volcano construction without major deformation, suggesting a relatively high value for the lithospheric thickness.

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